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UK/AUSTRALIAN TRIALS TO DETERMINE THE EFFECTS OF THE ACCIDENTAL INITIATION OF SMALL QUANTITIES OF EXPLOSIVES IN BRICK WALL BUILDINGS WITH CONCRETE AND LIGHT ROOFS

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ABSTRACT

The United Kingdom and Australian Explosives Storage and Transport Committees have a mutual interest in gaining a greater understanding of the effects of the accidental initiation of small quantities (<50kg) of explosives in small buildings, for example ready use magazines and processing facilities. The current UK, NATO and Australian Prescriptions advise the use of default distances considered to contain the debris and fragmentation effects from significantly greater quantities. This leads to the uneconomic use of assets or, at times, precludes their use entirely. A programme of work has been commenced under the terms of an Anglo-Australian Memorandum of Understanding to investigate the debris throw from explosions in typical Australian and UK brick wall buildings with concrete and frangible roofs.

This paper presents the results of the first half of this trials programme completed in May 1995 and an overview of the second half completed in May 1996. In the programme the debris throw from the detonation of charges of 25kg and 50kg in single and double (cavity) brick wall buildings with frangible and concrete roofs has been determined. The velocity and distribution of debris with and without the influence of a traverse are reported.

INTRODUCTION

1. In the past, much work has been done to determine the consequences of the initiation of large quantities of explosives in storage structures (References 1,2,3 for example). The results of such trials have formed a strong experimental base for the prescriptions of the United Kingdom and NATO used and adopted by many nations. By creating this base of experimental data it has been possible, to some degree, to control the amount of conservatism or safety factor built into the prescriptions and thus allow for the economic use of the assets of land and buildings. Such assets become more valuable and rarer every day and it is vital that their use be maximised wherever possible.

2. In the early nineties it became apparent that the safety management of small quantities of explosives offered considerable scope for similar economic improvements. The current application of default distances relevant to 500kg net explosive quantity (NEQ) for much smaller NEQs results in unrealistic building separations and in some cases the preclusion of explosives storage altogether. The argument has often been made that, because of the vastly differing requirements for such small quantity storage or handling it would be impossible to apply generic prescriptions. However, as the result of workshops run by UK ESTC and NATO AC/258 and internal discussion within the Australian Ordnance Council the need for information on the projection of brick walls by quantities of explosives up to 50kg was identified. The limit of 50kg sensibly encompassed the typical problems identified by the Nations. These ranged from the processing of munitions of one sort and another where the risk could be unitised to either one or small numbers to the secure parking of Ordnance Disposal vehicles with their specialist explosives on board or nearby.

PROGRAMME OF TESTS

3. In April 1993 a meeting between the Australian Department of Defence and the UK Ministry of Defence tasked the Explosion Effects and Trials Analysis Sub-committee of the Australian ESTC with developing a specification for tests to determine the explosion effects and consequences from the detonation of up to 50kg NEQ HD 1.1 explosive in a small explosives storehouse (ESH). The specification (Reference 4) is reproduced at Annex A.

4. For reasons of financial constraint and practicality of testing, the programme was divided into two phases, one to be carried out in April/May 1995 and the other during the same period in 1996.

5. The first phase for which the testing was completed on 19 May 1995 consisted of firings 3,4,5,6,7 and 9 of Table A1. Details of the firings in the order fired are given in Table 1 below.

TABLE 1 TEST SEQUENCE FOR THE FIRST TEST PHASE

TEST NO	WALL TYPE	WALL THICKNESS	ROOF TYPE	NEQ kg
1	ENGLISH BOND SINGLE BRICK	230mm	FRANGIBLE	50
2	ENGLISH BOND SINGLE BRICK	230mm	FRANGIBLE	25
3	ENGLISH BOND SINGLE BRICK	230mm	CONCRETE	50
4	ENGLISH BOND SINGLE BRICK	230mm	CONCRETE	25
5	DOUBLE BRICK CAVITY SPACED	270mm	FRANGIBLE	50
6	DOUBLE BRICK CAVITY SPACED	270mm	FRANGIBLE	25

6. The second phase for which the testing was completed on 22 April 1996 encompassed the remaining six firings of Table A1. Details of the firings in the order fired are given in Table 2 below.

TABLE 2 TEST SEQUENCE FOR THE SECOND TEST PHASE

TEST NO	WALL TYPE	WALL THICKNESS	ROOF TYPE	NEQ kg
1	SPECIAL UK DESIGN[1]	270mm	CONCRETE	50
2	DOUBLE BRICK CAVITY SPACED	270mm	CONCRETE	50
3	SPECIAL UK DESIGN[1]	270mm	CONCRETE	25
4	DOUBLE BRICK CAVITY SPACED	270mm	CONCRETE	25
5	DOUBLE BRICK CAVITY SPACED[4]	270mm	FRANGIBLE	10[2]
6	DOUBLE BRICK CAVITY SPACED[4]	270mm	FRANGIBLE	10[3]

Notes:
1. See Annex A for details.
2. 500mm stand-off from western wall.
3. 150mm stand-off from western wall.

PHASE 1 TEST DETAILS

Buildings

7. Buildings were constructed in accordance with the relevant paragraphs of Annex A and Appendix 1 to Annex A. All six concrete floor slabs were cast in a circular array around one of the Spantech igloos at the Woomera test site at a distance such that the debris collection areas did not intersect. Where pertinent, concrete roof slabs were also

cast at ground level close to their respective floor slab. On completion of the walls, and after the relevant curing period either the concrete roof slab was lifted into place or the frangible roof and security grid assembled. Earth traverses were then constructed on two sides of the building. Instrumentation conduits were laid under the traverses at ground level.

Charge Assembly

8. Charges comprising the relevant numbers of cast Australian produced Composition B blocks were assembled in wooden boxes. These boxes attached to wooden charge stands such that the height to the centre of the charge was one metre.

Instrumentation and Cine/Video

9. Pressure measurements were made in accordance with the specification.

10. Following success in its use in UK for the measurement of wall velocities, Doppler radar was provided by P&EE Port Wakefield. A Weibel PVME (Large Antenna) X Band radar with associated digital multichannel Fast Fourier analyzer was placed 300m and a few metres off the normal from the exposed wall of the building under test. In an endeavour to enhance the radar reflectivity of the brickwork a horizontal band of heavy metal content paint was applied to the relevant wall of the buildings for tests 3,5 and 6. In test 4 a metallic close weave net was glued to the wall for the same purpose.

11. High speed cine coverage of the event was in accordance with Appendix III to Annex A.

12. In addition to providing the Doppler radar system P&EE Port Wakefield also fielded two S-VHS video systems. These were placed at the 300m radius close to the radar and were used to record the overall event and, via a telephoto lens, the initial movement of the exposed wall from face on.

13. Debris collection and recording was carried out after each firing in accordance with the relevant parts of the specification. A team of 30 personnel was used to pick up the debris and recover it to the Spantech igloo where a team of technical staff from DSTO, Weapons systems Division, Aeronautical & Maritime Research Laboratories, Ascot Vale sorted and weighed it. Analysis of the results was then carried out by DSTO to provide lethal debris densities as a function of range and azimuthal angle. Further analysis was then carried out by the M J A Gould to generate the data in the trajectory normal (Reference 5) form presented below.

PHASE 2 TEST DETAILS

Buildings

14. Of the six concrete pads damaged in the first phase, four were refurbished by infilling the damage at the centres. The remaining four brick wall buildings were then constructed in accordance with Annex A on these bases. Because of the need to tie the two special UK structures to their bases, it was necessary to recast these at the same time as the construction of the building frame took place. In all other respects the buildings were constructed in accordance with the specifications.

Charge Assemblies

15. Charges were again assembled in compressed fibre board (CFB) boxes. To try and reduce the "focusing effect" thought to be caused by the solid CFB sides to the charge stands in Phase 1, open framework stands were used for Phase 2.

Instrumentation, Cine and Video

16. In the light of the excellent results produced by the SVHS video cameras during Phase 1, it was decided to use all video coverage for the second phase. In addition to the general recording quality, their use also allowed instant playback and thus the maximum ability to adjust camera positions and settings between firings. Where possible time displays were recorded simultaneously with the events.

17. Pressure measurement positions were the same as those in Phase 1 to give consistency across the test series.

18. Doppler radar was again employed for all firings. Special cast aluminium bricks were built into the western wall of the buildings in the hope that they might provide enhanced reflections. In addition a metallic paint band was applied across the middle of the wall.

19. Collection and sorting of brick debris was carried out in an identical manner to Phase 1. Also in zones FF50 and outwards and N50 and outwards complete mass distributions were measured.

PHASE 1 TEST RESULTS

Shock Pressure

20. Detailed results, where available, from the shock pressure measurements are detailed at Annex B. As might be expected in such an aggressive environment, a number of gauges were lost in each test and had to be replaced. Records were truncated in time when the walls or roof in which the gauges were mounted commenced breaking up and

moving, thus damaging cables and/or gauges. However, as can be seen from the example at Figure 1, good results were obtained and these will be used in the generation of the relevant empirical relationships needed to build the debris predictive model.

Doppler Radar

21. From Table 2 it can be seen that results from the Doppler Radar system were mixed. Initially communication problems between firing point and Radar instrumentation caused the loss of records. However, once this was resolved good results were achieved until Test 4 when, for unresolved reasons, the signal recording system failed to trigger. Further good results were obtained in the last two tests. Figure 2 shows a typical waterfall plot of velocity vs time generated by the Fourier analysis of the Doppler signal.

TABLE 2 SUMMARY OF PHASE 1 DOPPLER RADAR RESULTS (REFERENCE 6)

TEST NO	CHARGE WEIGHT (kg)	WALL TREATMENT	SIGNAL DURATION (ms)	MEASURED VELOCITY (M/S)
1	50	NONE	NO SIGNAL	NO RESULT
2	25	NONE	750	14-15
3	50	METAL PAINT	300	43-47
4	25	METAL MESH	NO SIGNAL	NO RESULT
5	25	METAL PAINT	900	16-18
6	50	METAL PAINT	990	14-20

22. The results clearly show the velocity enhancement produced by the increased quasi-static pressure in the concrete roofed structure (Test 3). Comparison of the cavity brick and solid brick results indicates that the cavity does not have a great effect on the initial wall velocity.

23. The possibility of extracting further more detailed debris velocity data from the Doppler radar signals is being discussed.

Video Records

24. In Test 1 results from both cameras showed clearly the venting effect of the roof. A rapidly expanding mushroom cloud formed immediately. The effect of the traverse in stopping much of the wall debris was clearly visible. Debris impacting the very top of the traverse was seen to be diffracted along with the traverse material into a "jet" flying initially horizontally but dropping rapidly. The more rapidly accelerated door with following cloud of combustion products can be seen leaving the rest of the expanding fireball. Close up

of the wall was not used in this first test and therefore little detail of its breakup could be seen.

25. For Test 2 the long range view gave similar results to that discussed for Test 1 above. However the second camera whose field of view was almost entirely filled by the side wall of the ESH showed graphically the breakup of the wall into, mainly, single brick units and their subsequent dispersal down range.

26. The distant view in Test 3 showed the roof of the ESH projected almost in one piece upwards and then falling back through the dust cloud some 10 seconds later. A rough calculation indicates that the roof was projected upwards over 120m. The close up of the wall showed much more breakup of the brickwork and more rapid dispersal of the debris from the initial flat array.

27. Results of Test 4 were similar to those of Test 3 except that the roof was projected over 75m and the wall breakup was a little less severe.

28. Tests 5 and 6 showed a return to the classic mushroom cloud gas release through the soft roof of the building and the dissociation of the wall into mainly brick size debris.

Cine Records

29. Due to logistics problems in getting feedback on cine results between firings, the films from some cameras in the first three firings gave no useable results. The velocities measured are as follows:

TABLE 3 FRAGMENT VELOCITIES OBTAINED FROM CINE FILMS (REFERENCE 7)

SHOT NO	ROOF/ CHARGE WEIGHT	AVERAGE FRAGMENT VELOCITIES (MS^{-1})				
		V1	V2	V3	V4	V5
1	FRANGIBLE 50KG	**	**	**	**	
2	FRANGIBLE 25KG	**	**	**	**	17
3	CONCRETE 50KG	**	**	**	**	67
4	CONCRETE 25KG	62	43	34	32	42
5	FRANGIBLE 50KG	38	34	33	25	22
6	FRANGIBLE 25KG	73	65	51	46	35

NOTES

1. V1, V2, V3 & V4 are average velocities measured from Camera C1.
2. V1 & V2 are average velocities of the fastest fragments visible.
3. V3 & V4 are average velocities of the main group of fragments
4. V1 & V3 are measured over the first 24.25m (29.25 in tests 4 & 5)
5. V2 & V4 are averaged over the next 8m of travel.
6. V5 is measured using camera C2 and will only resolve larger pieces of debris.

** Films not suitable for quantitative analysis.

Debris Collection and Analysis

30. Potentially lethal debris were collected by zone, counted and weighed. From this data debris densities were calculated as a function of distance from ground zero and direction. For untraversed walls, it was noticeable that, close to the original wall position there was little debris close to the original wall position. The debris density began to build from about 10m out, increased to a peak and then decreased with increased range. The position of the peak was dependant on the circumstances of the individual test. Typical maximum debris throw and range at which the lethal debris density falls to $1/55.7m^2$ (the generally accepted density at IBD) are shown graphically in Figures 3 and 4. The distances in the major directions are summarised in Tables 4 and 5.

TABLE 4 RANGE AT WHICH A DEBRIS DENSITY OF $1/55.7M^2$ IS ACHIEVED

TEST NO	FRONT	SIDE	TRAVERSED SIDE	BACK
1	130	130	90	90
2	130	90	70	50
3	190	170	150	170
4	150	150	110	130
5	130	90	110	90
6	130	110	110	70

TABLE 5 MAXIMUM RANGE OF DEBRIS IN MAJOR DIRECTIONS

TEST NO	FRONT	SIDE	TRAVERSED SIDE	BACK
1	210	110	90	90
2	130	90	90	70
3	210	270	190	210
4	250	170	130	130
5	190	90	110	110
6	210	130	130	170

PHASE 2 RESULTS

Shock Pressure

Detailed results (Reference 6), where available, from the shock pressure measurements are detailed at Annex C. Again, where possible these results will be used in the generation of the relevant empirical relationships needed to build the debris predictive model.

Doppler Radar

Detailed results from the Doppler Radar signals (Reference 7) are given in Table 6 below.

TABLE 6 DEBRIS VELOCITIES MEASURED USING DOPPLER RADAR ON THE WEST WALLS OF THE BUILDINGS

TEST NO	BUILDING/ ROOF	NEQ (KG)	MEASURE TIME MS	VELOCITY RANGE (MS^{-1})	AVERAGE VELOCITY (MS^{-1})	S/N RATIO (dB)
2	DBCS/ CONCRETE	50	29-450	89-171	140	2-9.8
2	"	"	450-900	119-160	135	2-7.5
2	"	"	900-1350	120-150	131	1-6.1
2	"	"	1350-1800	115-157	135	1-6.6
6	DBSC/ FRANGIBLE	10	0-550	117-163	134	1-7.0
6	"	"	550-1100	120-170	136	1-7.0
6	"	"	1100-1650	120-160	138	1-8.5
6	"	"	1650-2200	117-150	138	1-6.6
5	DBSC/ FRANGIBLE	10	0-625	107-180	136	1-6.0
5	"	"	625-1250	110-170	133	1-7.2
5	"	"	1250-1875	110-165	136	1-6.9
5	"	"	1875-2500	112-174	135	1-7.7
4	DBSC/ CONCRETE	25	0-700	110-158	123	1-7.3
4	"	"	700-1400	102-170	133	1-6.4
4	"	"	1400-2100	114-162	133	1-7.2
4	"	"	2100-2800	114-170	137	1-5.1
4	"	"	2800-3500	114-180	140	1-10
4	"	"	2800-3500	7-23		1-10
3	UK DESIGN CONCRETE	25	0-450	114-157	134	2-7.4
3	"	"	450-900	102-157	128	1-6.6
3	"	"	900-1350	107-170	131	1-7.6
3	"	"	1350-1800	100-160	131	1-7.0
1	UK DESIGN CONCRETE	50	0-700	97-200	154	1-6.4
1	"	"	700-1400	113-171	139	1-6.8
1	"	"	1400-2100	113-161	136	1-6.0

TABLE 6 CONTINUED

TEST NO	BUILDING/ ROOF	NEQ (KG)	MEASURE TIME MS	VELOCITY RANGE (MS^{-1})	AVERAGE VELOCITY (MS^{-1})	S/N RATIO (dB)
1	"	"	2100-2800	109-161	133	1-9.0
1	"	"	2800-3500	109-170	136	1-5.4
1	"	"	3500-4200	112-165	136	1-5.0

The results are significantly different to those determined for the first phase of the tests and show no apparent correlation with the size of the charges used. Careful examination of the video recordings (see below) shows a "jet" of material projected from the point on the wall directly opposite the charge. It may be that this is being detected by the radar and not, as had been expected, the main bulk of the wall. This is being investigated further.

Video Records

31. Three cameras were deployed to capture the debris throw from the same wall as was monitored by the Doppler radar. The velocities measured are given in Table 7.

32. Dust limited the velocity measurements to those for large pieces of debris. Despite this the records gave a good indication of the spread of debris and the mode of breakup of the walls. The jetting immediately in front of the charge could be seen in some frames and further analysis is to be carried out to determine these jet velocities where possible. The concrete roofs were projected upwards almost intact. Some breakup of the edges could be seen, in particular with the UK designed buildings where the roof perimeters were tied to the wall lintels and corner posts. The posts were projected in one piece, the posts along the diagonals of the buildings to 20-30 metres and the lintels at approximately 45^{o} to the ground and normal to the walls to a range of 30 metres or more.

TABLE 7 DEBRIS VELOCITIES FOR THE WEST WALLS OF THE BUILDINGS MEASURED FROM VIDEO CAMERA RECORDS

TEST NO	NEQ (KG)	BUILDING TYPE ROOF	WALL VELOCITY (MS^{-1})	ROOF PROJECTION HEIGHT (M)
1	50	UK DESIGN CONCRETE	42-100	OUT OF VIEW
2	50	DBSC CONCRETE	71-100	OUT OF VIEW
3	25	UK DESIGN CONCRETE	62.5	OUT OF VIEW
4	25	DBSC CONCRETE	71.4	102.6
5	10 0.5M S/OFF	DBSC FRANGIBLE	42-50	BROKE UP
6	10 0.15M S/OFF	DBSC FRANGIBLE	35.7-62.5	BROKE UP

Debris Collection and Analysis

33. The debris was collected in accordance with the Specification (Reference 4). However at the time of writing the data had not been received or analyzed.

CONCLUSIONS

34. The detonation of 25kg and 50kg charges in small brick wall buildings generates directionally dependent debris distributions.

35. Brick debris ranges are enhanced by the use of reinforced concrete roofs rather than frangible roofs.

36. A hole is blown in the centre of the concrete roof generating a scatter of concrete debris. The major part of the roof is projected more or less vertically.

37. Whilst traverses stop some debris, that hitting the top is "diffracted" and produces a significant debris field beyond the traverse.

38. Walls move outwards as a planar array of dissociated bricks and part bricks. Dispersal of this array commences when the foot of the wall contacts the ground and starts dragging.

39. Initial wall velocities are around $45ms^{-1}$ for concrete roof buildings and 14-20 ms^{-1}

for frangible roof buildings. There is some evidence of a "jet" of debris being projected at a much higher velocity from the wall directly opposite the charge. The amount projected does, however appear to be small.

40. Concrete roofs will be thrown in excess of 120m in the air with a charge weight of 50kg.

41. The UK designed buildings with reinforced concrete corner pillars and lintels do not provide any advantage at the NEQ and loading density regimes tested.

42. Doppler radar will give information on the initial movement of walls though there are still problems in interpretation. Aluminium bricks do little to enhance the Doppler return signals.

43. High speed video has given excellent definition records of early wall breakup and roof movement.

44. Whilst pressure gauge mortality rates are high, valuable data has been generated for eventual use in model generation.

FUTURE WORK

45. To discuss the possible extension of joint Australia/UK trials to extend the range of NEQs to 100kg or more.

46. From the data being generated, to develop extensions to the SwRI DISPRE model to cover brick wall buildings and to improve the roof projection algorithms.

47. To use the data being generated to provide users with soundly based advice on safe storage and process building separations where small quantities of explosives are involved.

48. To generate comprehensive small quantity consequence models for use in risk analysis.

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6. Private Communication, DST 95-8966 D TRIALS 716/96 of 10 July 1996.

7. Australian Army Trial Report, Small Quantity Explosive Storehouse Trial 8/126 Phase Two; W G Manners; 30 May 1996.

FIGURES

1. Typical Pressure Pulse

2. Typical Doppler Radar Waterfall Plot of Velocity vs Time

3. Range (m) at which the Lethal Debris Density Falls below 1/55.7m^2 for Test 6.

4. Range (m) of Maximum Debris Throw for Test 6

ANNEXES

A. Small Quantity Trials to Take Place at Woomera, South Australia

B. Tables of Shock Pressures for Phase 1, Tests 1 to 4

C. Tables of Shock Pressures for Phase 2, Tests 2 to 6

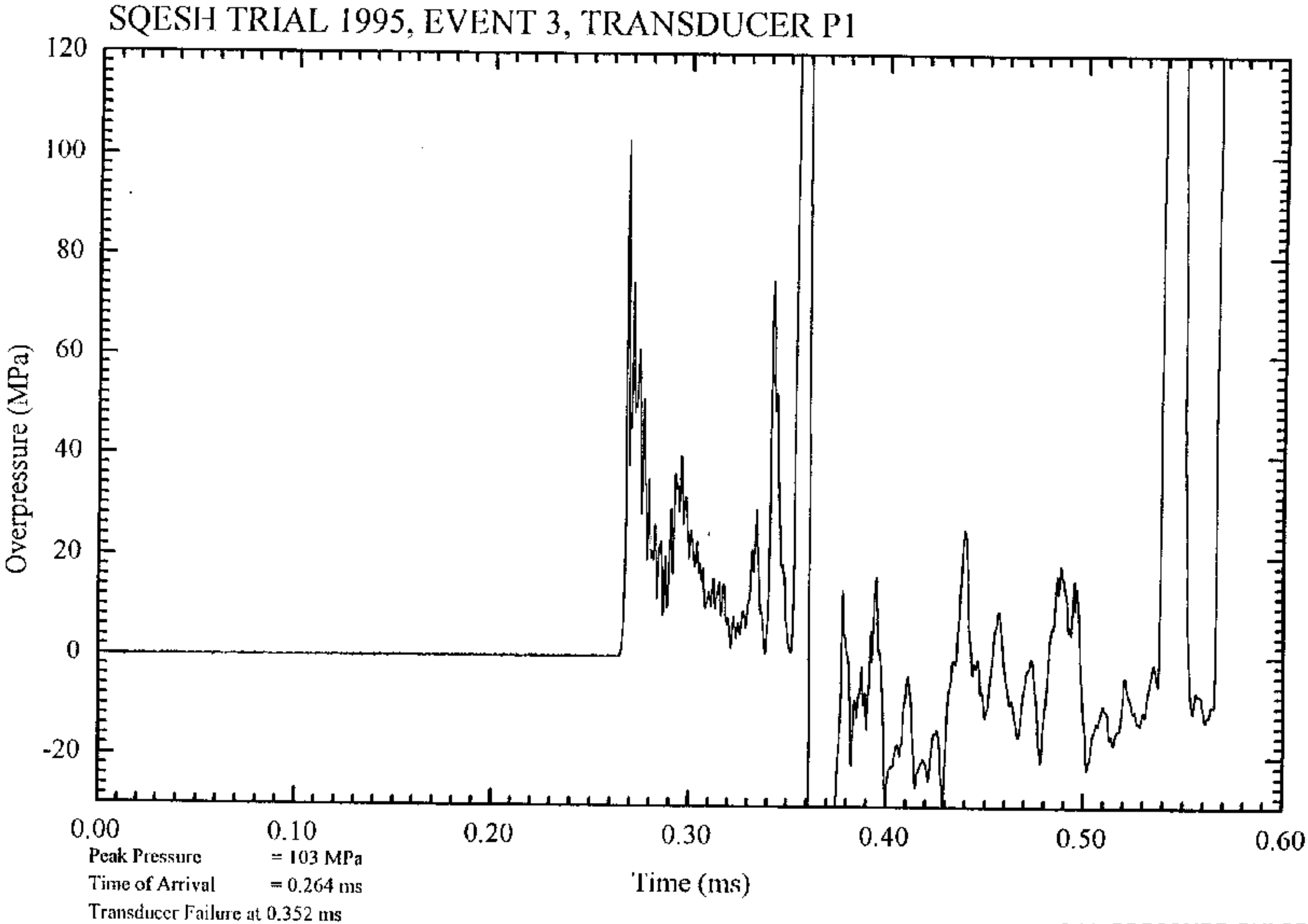
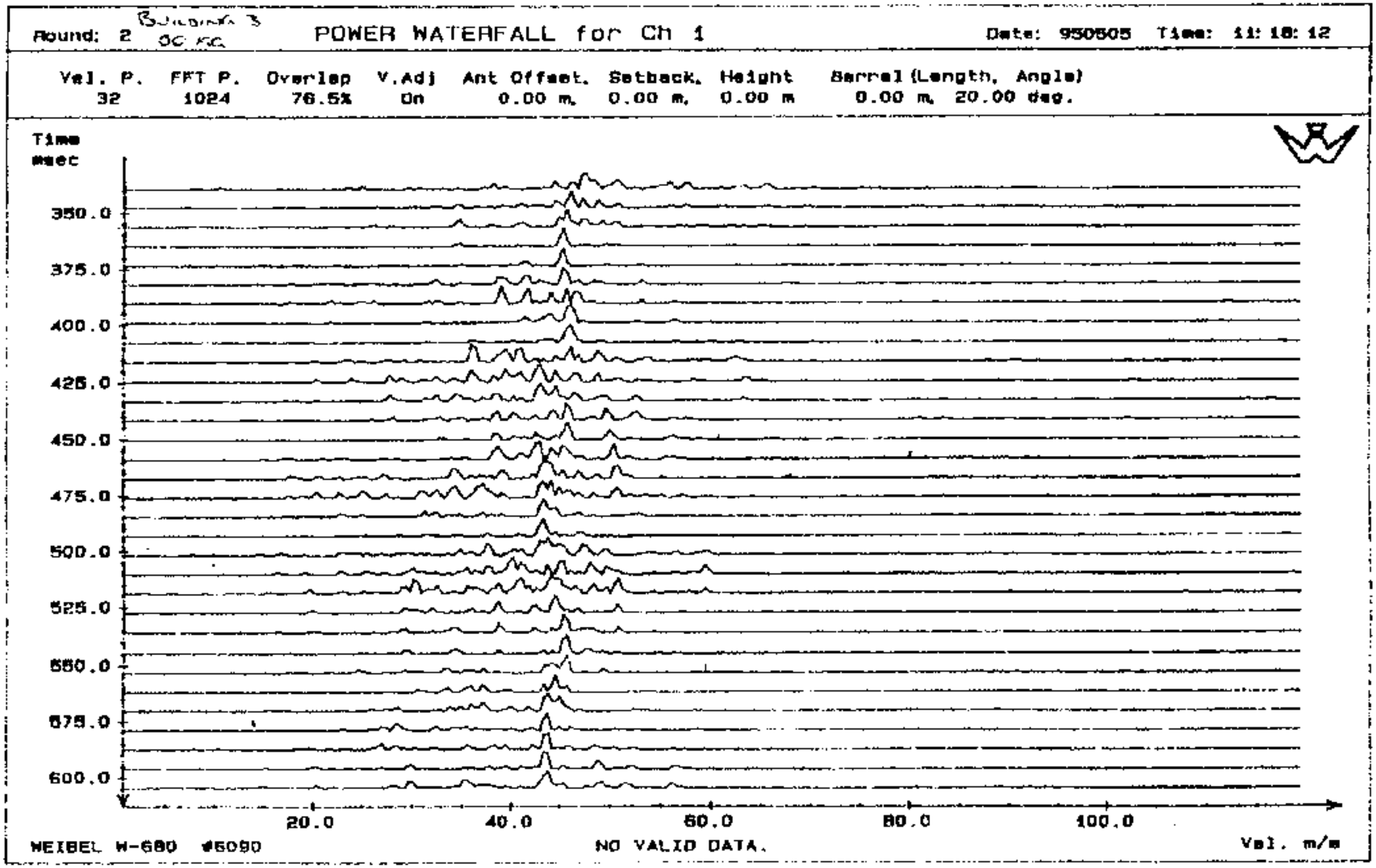


FIGURE 1 TYPICAL PRESSURE PULSE

FIGURE 2 TYPICAL DOPPLER RADAR WATERFALL PLOT OF VELOCITY VS TIME



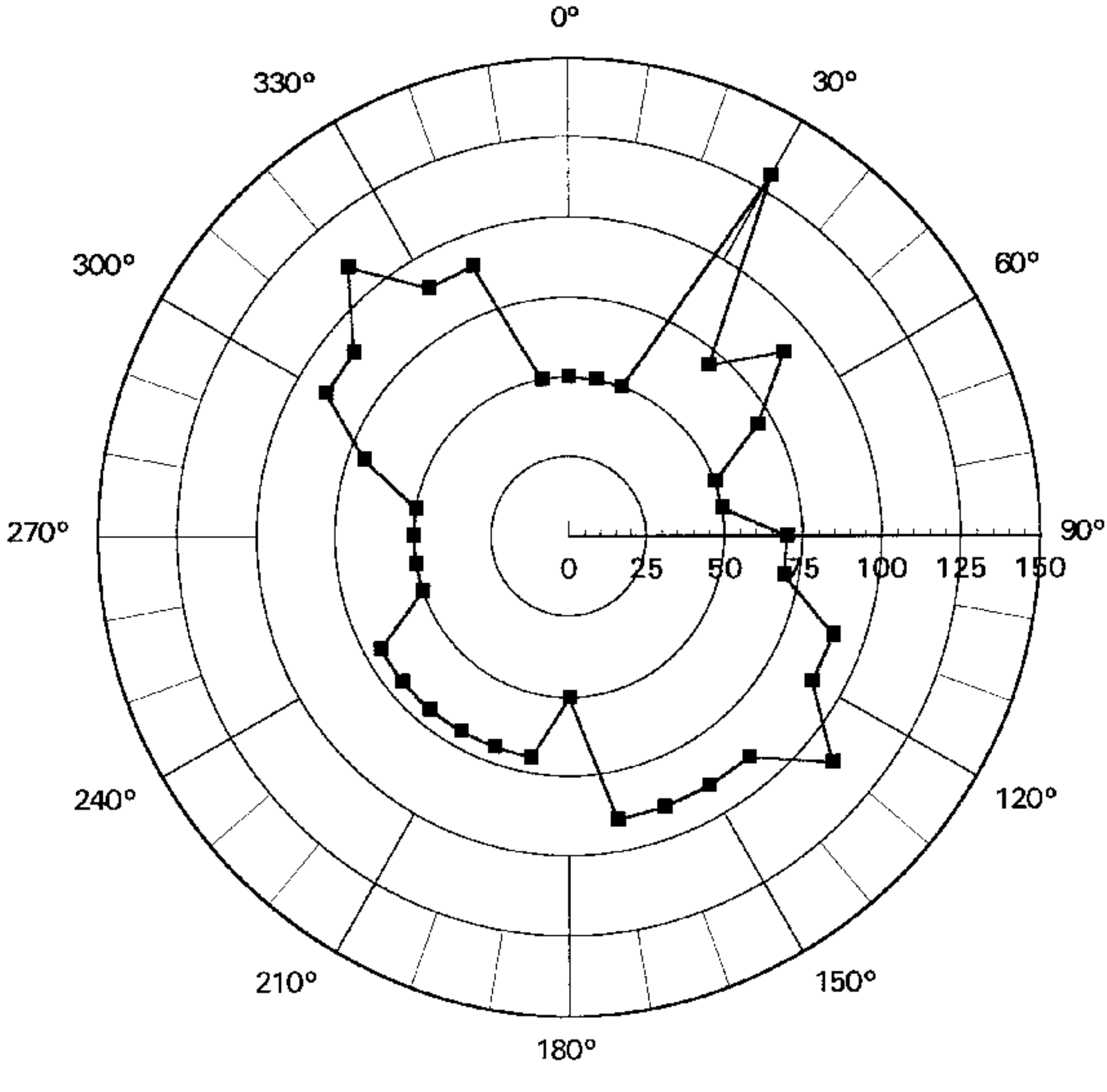


Figure 3 Range at which the lethal density falls below 1/55.7 sq m for test 6

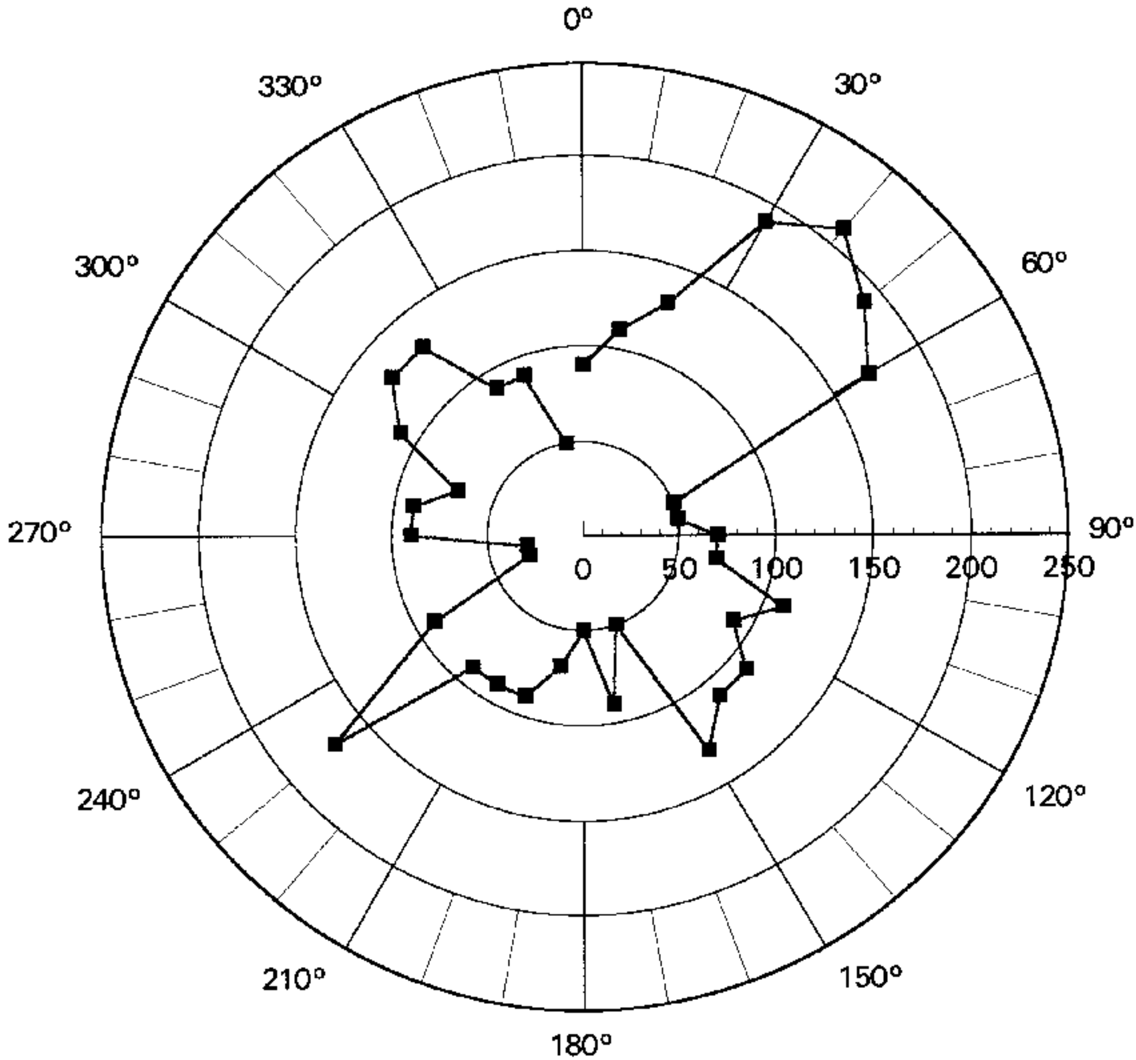


Figure 4 Range of maximum fragment throw for test 6

ANNEX A

SMALL QUANTITY TRIALS TO TAKE PLACE AT WOOMERA, SOUTH AUSTRALIA

INTRODUCTION

A1 In early 1993, representatives of the Australian Department of Defence and the United Kingdom Ministry of Defence met in Canberra to consider future joint AS/UK explosives effects trials following completion of the recent series of successful large scale STACK FRAGMENTATION trials at Woomera South Australia.

A2. It was recognised that further trials were needed to obtain additional large magazine data and also to obtain data on the explosion effects characteristics of explosions in small quantity explosives storehouses (ESH) ie ESH holding 50 kg TNT equivalent net explosive quantity (NEQ) or less. A series of six small quantity trials was proposed.

A3. A trials outline was forwarded to the UK in September 1993 for NATO AC/258 Small Quantities Workshop consideration. Further refinement of the trials plan occurred during the visit of UK ESTC representatives to Australia in October and November 1993 and the consideration of written comments from the UK that arrived in January 1994. The consequence of these reviews was that twelve tests are now proposed, ten "joint" and two "special to UK". A formal request for trial was submitted and this subsequently has been accepted by the Australian DoD Directorate of Trials as DEF TRIAL 8/626.

AIM

A4. The aim of the trial is to determine the effects of a detonation of up to 50 kg NEQ HD 1.1 explosive in a small quantity ESH.

LIMITATIONS

A5. The following limitations were imposed on planning:

a. four brick ESH building types to meet joint AS/UK requirements were specified:

(i) English bond solid brick (EBSB) single bay with frangible roof (FR).

(ii) Double brick cavity spaced (DBCS) single bay with FR.

(iii) EBSB single bay with heavy reinforced concrete roof (RCR).

(iv) DBCS single bay with RCR.

b. In addition a low cost brick ESH of UK design with concrete roof and reinforced concrete column enhancement (in accordance with UK DWS specification D/DWS 27/42/1/3 dated 5 Jan 1994) was to be tested under separate funding arrangements initiated by the UK.

c. Three NEQs were specified:

(i) 10 kg NEQ TNT equivalent,

(ii) 25 kg NEQ TNT equivalent,

(iii) 50 kg NEQ TNT equivalent.

TRIAL OUTLINE

A6. Twelve small quantity brick ESH of a type typical of small unit magazines are to be constructed. The buildings will be a mixture of single cell EBSB or DBCS magazines with light frangible or heavy reinforced concrete roofs and special UK design magazines. A 10 kg, 25 kg or 50 kg TNT explosive charge will be detonated inside each ESH. The ESH experiencing the 25 kg or 50 kg detonations will be traversed on two sides only to enable comparisons of fragmentation trajectories. The matrix at Table 1 defines the ESH by type of design and explosives loading.

TABLE A1 PROPOSED JOINT AS/UK SMALL QUANTITY ESH FRAGMENTATION TRIALS

SERIAL	BUILDINGS/COMMENT	NEQ (kg)
1.	DBCS frangible roofed ESH untraversed, charge to be centrally located.	10kg HD 1.1 (non-fragmenting) (nf)
2.	DBCS frangible roofed ESH untraversed, charge to be located 1.0 m above floor and 0.5 m from wall opposite door.	10 kg HD 1.1 (nf)
3.	EBSB frangible roof - semi traversed	25 kg HD 1.1 (nf)
4.	DBCS frangible roof - semi traversed	25 kg HD 1.1 (nf)
5.	As for serial 3	50 kg HD 1.1 (nf)
6.	As for serial 4	50 kg HD 1.1 (nf)
7.	EBSB reinforced concrete roof - semi traversed	25 kg HD 1.1 (nf)
8.	DBCS reinforced concrete roof - semi traversed	25 kg HD 1.1 (nf)
9.	As for serial 7	50 kg HD 1.1 (nf)
10.	As for serial 8	50 kg HD 1.1 (nf)
11.	RC Column Heavy Roof - semi traversed	25 kg HD 1.1 (nf)
12.	RC Column Heavy Roof - semi traversed	50 kg HD 1.1 (nf)

OBJECTIVES

A7. The trial objectives are to obtain the following data:

a. The dispersion of fragmentation and the derivation of fragment energy density contours.

b. The fragmentation containing effects of traverses - 25 kg and 50 kg detonations.

c. Overpressure vs time measurements as detailed in Appendix II.

d. High speed cine cover of:

(i) side and rear wall movement,

(ii) ESH roof movement,

(iii) fragment projection and fragment velocities in the near and extended fields in order that full trajectories for as many fragments as possible can be derived,

(iv) fragmentation roll and bounce.

GENERAL ESH DESIGN CRITERIA

A8. Test building construction is to be based on the Army magazine design drawings at Figures A1 and A2 and the UK design at Figure A3, with design and construction detail as specified in the following paragraphs. To simplify instrumentation and trial site preparation, and if feasible, the magazines may be pre-constructed on reinforced concrete slabs and trucked to the trial site as required for test.

A9. Internal dimensions: 3 x 3 x 2.4 m (L x W x H)

A10. Wall types:

a. EBSB construction of 230 mm thickness where specified

b. DBCS construction of 270 mm thickness where specified

c. Bricks used for the EBSB are to be a different colour to those used for the DBCS construction.

d. Construction details are given at Appendix I.

A11. Floors: Floors are to be 150 mm RC cast in situ with integral footings, reinforced top and bottom with F82 mesh. There is to be a 10 day curing time before erecting brickwork. Increased thicknesses and reinforcing may be required if transportable, pre-constructed magazines are used.

A12. Roofs:

a. Frangible: Fibro cement single pitch on 75 x 38 battens @ 900 centre line.

b. Heavy RC: Cast in situ 150 mm concrete reinforced top and bottom. Cure time 28 days.

A13. Doors: Centrally located on the front of each building. A 50 mm solid wood core door with a security layer of 1.6 mm steel sheet on the external face is to be constructed. Normal hinges and bolt closures are to be fitted.

A14. Fittings: Amplimesh security mesh is to be fitted inside the frangible roof buildings at ceiling level. Metal conduit representing electric reticulation conduit is to be fitted to replicate a typical lighting wiring configuration. No shelves, windows or skylights are to be fitted.

A15. Traverses: A double earth slope traverse (to UK ESTC Leaflet 6 prescriptions)

level with the ESH eaves is to be constructed for the 25 kg and 50 kg NEQ ESH trials (ie 10 kg NEQ trial ESH are not to be traversed). The ESH are to be traversed at the back and left walls. The doors are not to be shielded by traverses. As the trials are unlikely to cause major damage to the traverses, only one set of traverses needs construction. Some refurbishment may be necessary after each firing.

EXPLOSIVE TYPE, PLACEMENT AND INITIATION

A16. Ten, 25 kg and 50 kg encased or lightly cased TNT or TNT equivalent charges, assembled from 5 kg blocks, with a density greater than 1.5 Mgm^{-3} are to be prepared for the trials. Single point initiation using an EBW (exploding bridgewire) detonator is required. Imaging equipment "run-up" and instrumentation time zero requirements are to be incorporated into the charge firing circuitry. For the 25 kg and 50 kg firings the charge will be placed 1 m above the floor in the centre of the ESH. For the 10 kg NEQ tests, the charges will be placed centrally, 600mm from the rear wall and 1m above the floor.

INSTRUMENTATION REQUIREMENTS

A17. Gauges: Pressure gauges to measure the pressure/time and impulse experienced by the walls are to be positioned in accordance with Appendix II. The calculated peak pressures, impulses and pressure pulse lengths will be provided separately. It is anticipated that gauges in the test ESH may be damaged beyond repair.

A18. High Speed Imaging: High speed imaging cameras (either cine or video) will be required for each firing to obtain the data requirements at para 7.e. Details are given at Appendix III.

FRAGMENTATION SEARCH AND ASSESSMENT

A19. A full fragmentation search pattern extending outward from the blast epicentre is required to ranges where no further brick, concrete etc debris is visible is required. A 360° polar survey extending to 300m centred on the GZ (centre of the test ESH) is to be conducted. 10° sectors with 20 m long segments are to be surveyed and peg marked. Brick and concrete debris of size greater than 50 mm in any dimension is to be recorded. Metal debris of any size is to be recorded. In the inner 20 m radius circle a search is to be made in one of the four quadrants only (an untraversed one) to ascertain the total mass of concrete and brick debris above 50 mm in any dimension.

SITE LOCATION

A20. A clear, level site for the trial is to be selected. The site is to be free of debris and undergrowth to simplify fragment collection and subsequent site clean-up.

FIGURES

A1. Single Bay ESH, Frangible Roof.

A2. Single Bay ESH, Heavy Reinforced Concrete Roof.

A3. UK ESH with RC Columns.

APPENDICES

I. Magazine Construction Details

II. Pressure Measurement Details

Ill High Speed Imaging Details

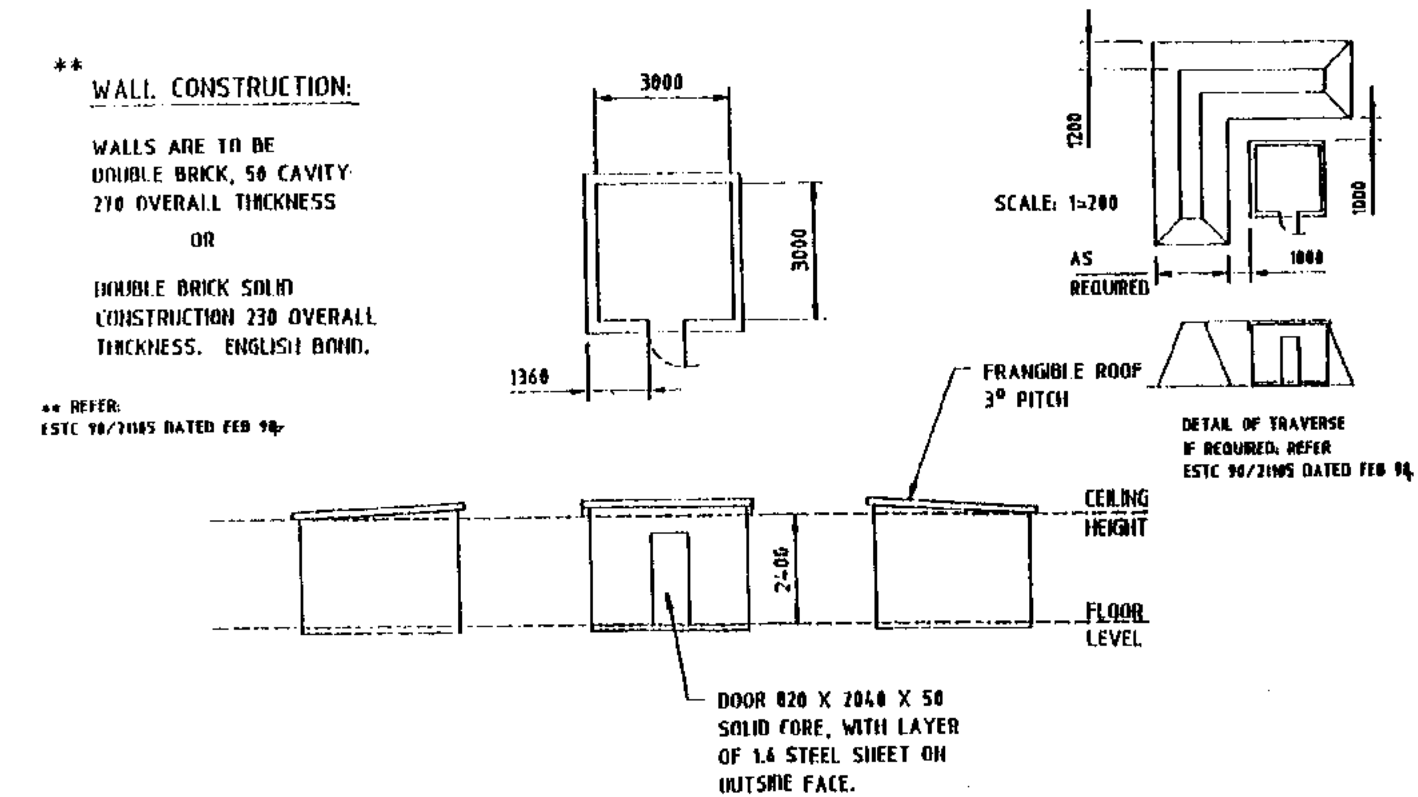


FIGURE A1 - SINGLE COMPARTMENT FRANGIBLE ROOF

ISSUE	DESCRIPTION OF CHANGE	DATE	DRAWN	DATE 10/2/91

AUSTRALIAN ARMY
ENGINEERING DEVELOPMENT ESTABLISHMENT

TITLE: FIG 1 - SINGLE COMPARTMENT FRANGIBLE ROOF

PROJECT IDENTIFICATION
SHEET 1 OF 1
A3

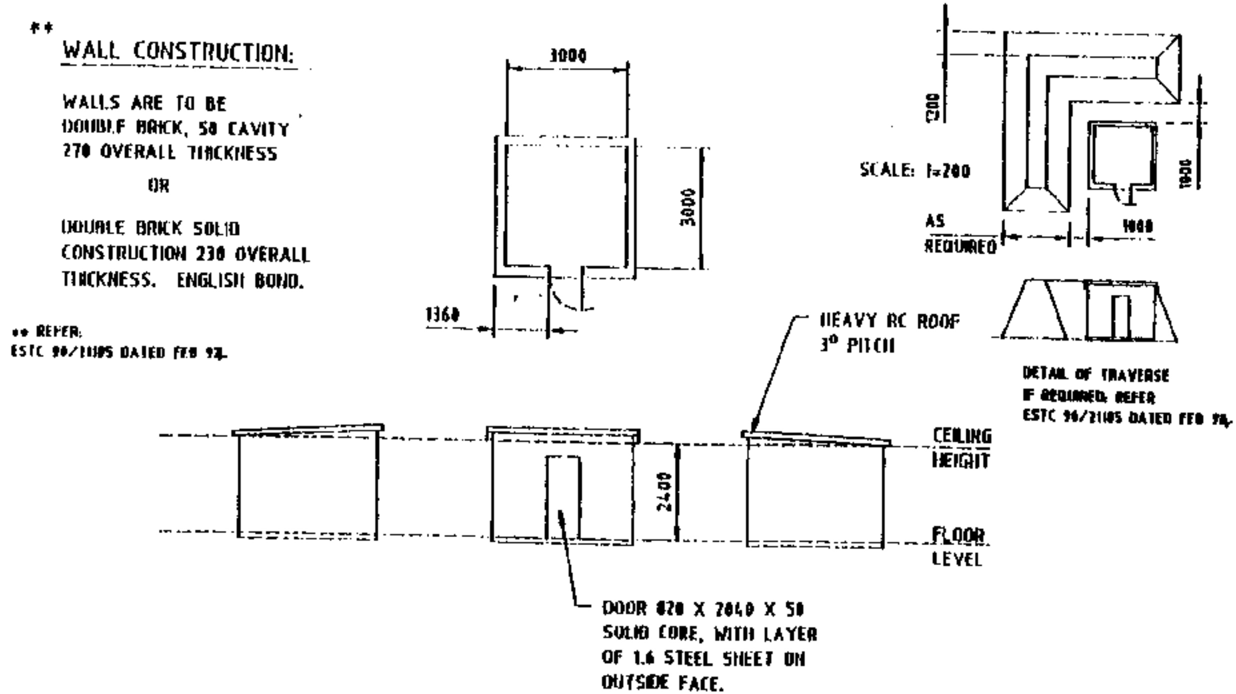


FIGURE A2 - SINGLE COMPARTMENT HEAVY RC ROOF

ISSUE | DESCRIPTION OF CHANGE | DATE

DRAWN

AUSTRALIAN ARMY
ENGINEERING DEVELOPMENT ESTABLISHMENT

TITLE FIG 2 - SINGLE COMPARTMENT
HEAVY RC ROOF

PROJECT IDENTIFICATION

SHEET 1 OF 1

A3

NOTES

1. GROUND SLAB THICKENING/FOUNDATIONS, TO SUIT GROUND CONDITIONS.
2. R.C. COLUMNS TO BE MOUNTED AT 5M CENTRES MAXIMUM, AND AT ALL CORNERS.
3. CONCRETE GRADE C35 MINIMUM.
4. REINFORCEMENT - MAIN AND SECONDARY - HOT ROLLED HIGH YIELD.

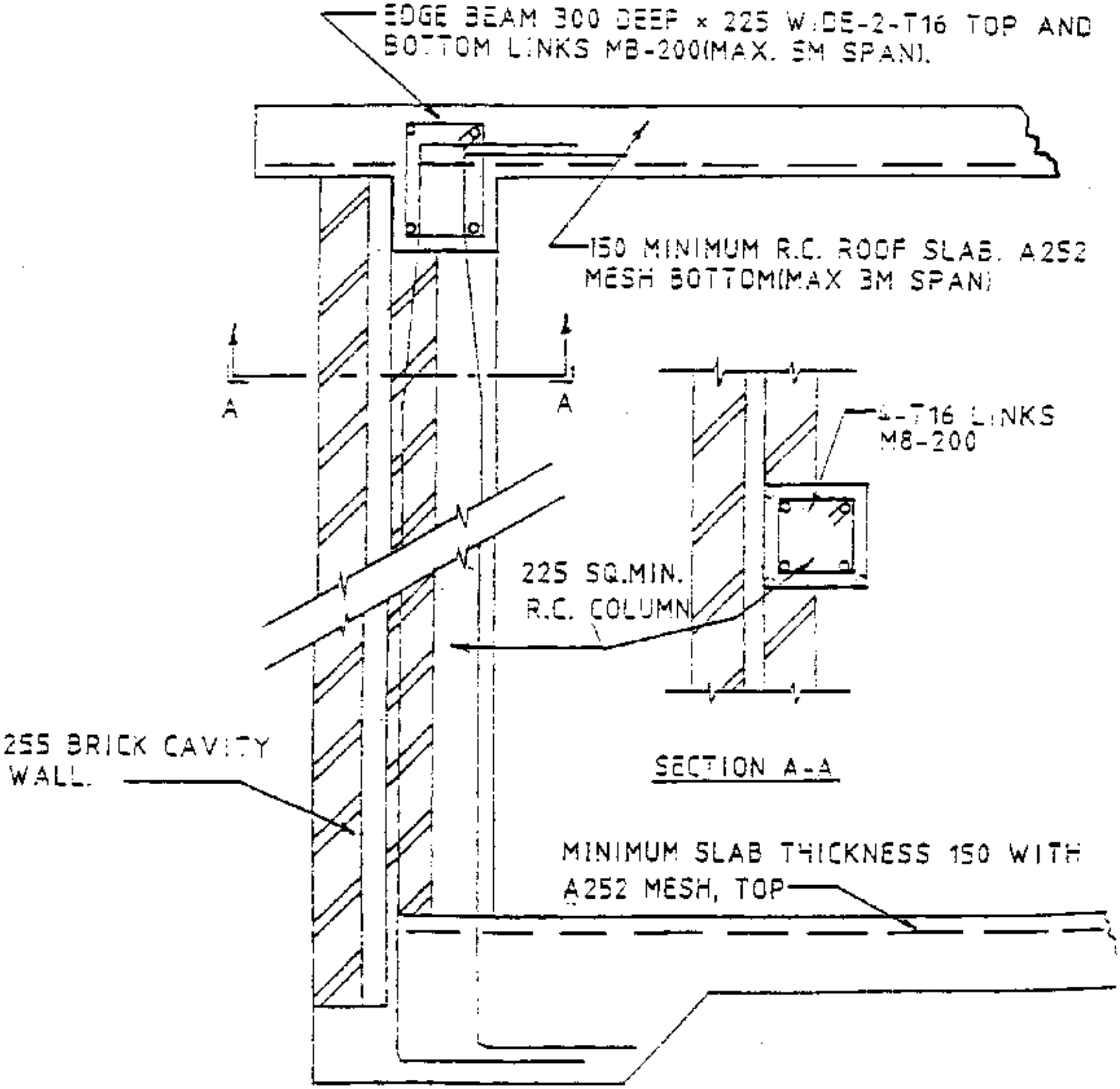


FIGURE A3 - ESH WITH RC COLUMNS

APPENDIX I

MAGAZINE CONSTRUCTION DETAILS

1. Magazines will be constructed to the general dimensions shown in Figures 1 to 3 of the main text and according to the trial program laid out at Table 1.

2. It has been suggested that it may be possible to construct the buildings on rigid bases such that they can be lifted into place as and when required. If portable buildings prove to be impracticable or post test debris cannot be removed then additional test arenas will be needed. Details of the reinforced concrete floor for the portable buildings are to be provided separately if required.

3. Magazines consisting of:

   a. solid brick walls 230 mm thick using English Bond as the bond pattern, or

   b. cavity brick walls 270 mm thick using standard stretcher bond as the bond pattern with standard ties at 450 mm intervals vertically and 900 mm horizontally, the inner wall to be a different colour brick to the outer wall;

are to be constructed in accordance with the trials schedule. Walls shall be provided with a damp proof course laid across the full width of the wall and at least 150 mm above the ground. Damp proof courses will be a membrane type complying with AS 2904.

4. Bricks shall be solid clay building bricks conforming to AS 1225-1984 with a single frog and manufactured to "traditional brick" dimensions (230 mm x 110 mm x 76 mm). The characteristic compressive strength of the bricks will be between 25 MPa and 50 MPa.

5. The mortar used in the construction of the walls will be cement/lime/building sand in the ratio 1:1:6. The mortar constituents will comply with Australian Standards set out in AS 3700.

6. Brickwork must be kept damp for at least 7 days to enable full curing to take place.

7. At least 28 days must be allowed between construction and trial.

8. The concrete roof slab will be 150 mm thick reinforced top and bottom in each direction with mesh reinforcement to achieve a reinforcement ratio of at least 0.175% by cross section area.

APPENDIX II

PRESSURE MEASUREMENT DETAILS

1. For 10 kg tests where the charge will not be placed in the centre of the magazine the following pressure measurement positions are to be monitored:

   a. On the wall closest to the charge, directly opposite the charge.

   b. On the wall closest to the charge, 1 m to the side of gauge a.

   c. Beside and half way up the door.

   d. In the centre of the ceiling

   e. In the centre of the wall to the left of the charge when looking at the wall closest to the charge.

2. For the 25 kg and 50 kg tests where it is intended to place the charge in the centre of the magazine the following pressure measurement positions are to be monitored:

   a. On the wall opposite the door directly opposite the charge.

   b. On the wall to the right of the charge when looking at the door, directly opposite the charge.

   c. In the centre of the ceiling.

   d. Beside and half way up the door.

   e. 150 mm below the ceiling on the centre line of the wall to the right of the charge when looking at the door.

3. Gauges and associated recording equipment must be capable of recording the pressure on the inner surface of the wall as a function of time and integrating the pressure pulse to give the impulse on the wall.

4. An additional pressure gauge will be required outside the magazine, 10 m in front of the door.

5. Based on the results obtained in the initial tests, gauge requirements may be changed for subsequent tests.

APPENDIX III

HIGH SPEED IMAGING DETAILS

1. The object of the video/cine coverage of the events to gather the maximum information on the projection of debris from the walls and roof of the magazine when it is disrupted by the explosion. Ideally, sufficient information should be gleaned from the records to define the complete trajectories of debris including any bounce or roll that may occur after initial impact.

2. Evidence from US work indicates that the debris is projected more or less normal to the surface of the wall or roof at velocities around 100 ms^{-1}.

3. The initial movement of the wall and its breakup are to be recorded and then coverage of the rest of the trajectory should be sufficient to permit debris of half brick size to be resolved. If possible the individual debris picked up in the field should be associated with the data from the video/cine records.

4. A camera is to be positioned to record the initial breakup and movement of the roof.

ANNEX B

TABLES OF SHOCK PRESSURES FOR TESTS 1 TO 4 OF PHASE 1

TABLE B1 SHOCK PRESSURE RESULTS FOR TEST ONE

PRESSURE TRANSDUCER	PEAK PRESSURE (MPa)	TIME OF ARRIVAL (ms)	TRANSDUCER FAILURE (ms)	MOUNT
P1	49	0.321	0.53	WALL BESIDE DOOR
P2	77	0.314	0.32?	WALL ADJACENT TO DOOR
P3	13	0.725	2.04	WALL ADJACENT TO DOOR NEAR CEILING
P4	92	0.309	0.76	WALL OPPOSITE TO DOOR
P5	78	0.258	0.34	CEILING DIRECTLY ABOVE CHARGE
P6	0.23	17.5	NO FAILURE	GROUND, LEAD BLOCK AT 10M

TABLE B2 SHOCK PRESSURE RESULTS FOR TEST TWO

PRESSURE TRANSDUCER	PEAK PRESSURE (MPa)	TIME OF ARRIVAL (ms)	TRANSDUCER FAILURE (ms)	MOUNT
P1	31	0.376	24	WALL BESIDE DOOR
P2	45	0.277	0.30?	WALL ADJACENT TO DOOR
P3	16	0.783	26	WALL ADJACENT TO DOOR NEAR CEILING
P4	37	0.321	0.351	WALL OPPOSITE TO DOOR
P5	87	0.302	0.409	CEILING DIRECTLY ABOVE CHARGE
P6	NO RECORD			GROUND, LEAD BLOCK AT 10M

TABLE B3 SHOCK PRESSURE RESULTS FOR TEST THREE

PRESSURE TRANSDUCER	PEAK PRESSURE (MPa)	TIME OF ARRIVAL (ms)	TRANSDUCER FAILURE (ms)	MOUNT
P1	103	0.264	0.352	WALL BESIDE DOOR
P2	218 or >243	0.192	0.238	WALL ADJACENT TO DOOR
P3	52	0.553	4.84	WALL ADJACENT TO DOOR NEAR CEILING
P4	138?	0.184	0.186	WALL OPPOSITE TO DOOR
P5	>240	0.012	0.092	CEILING DIRECTLY ABOVE CHARGE
P6	0.111	17.2	NO FAILURE	GROUND, LEAD BLOCK AT 10M

TABLE B4 SHOCK PRESSURE RESULTS FOR TEST FOUR

PRESSURE TRANSDUCER	PEAK PRESSURE (MPa)	TIME OF ARRIVAL (ms)	TRANSDUCER FAILURE (ms)	MOUNT
P1	26 @ 0.739ms	0.404	8.2	WALL BESIDE DOOR
P2	63 @ 0.312ms	0.291	0.317	WALL ADJACENT TO DOOR
P3	15 @ 0.973ms	0.753	14	WALL ADJACENT TO DOOR NEAR CEILING
P4	19.5 - 184?	0.310	0.312	WALL OPPOSITE TO DOOR
P5	56 @ 0.338ms	0.331	0.361	CEILING DIRECTLY ABOVE CHARGE
P6	104 @ 20.7ms	20.5	NO FAILURE	GROUND, LEAD BLOCK AT 10M WITH HEAT PROTECTION
P7	79 @ 20.7ms	20.5	NO FAILURE	GROUND, LEAD BLOCK AT 10M WITHOUT HEAT PROTECTION

ANNEX C

TABLES OF SHOCK PRESSURES FOR TESTS 2 TO 6 OF PHASE 2

TABLE C1 SHOCK PRESSURE RESULTS FOR TEST TWO

PRESSURE TRANSDUCER	PEAK PRESSURE (MPa)	TIME OF ARRIVAL (ms)	TRANSDUCER FAILURE (ms)	MOUNT
P1	>96.7	0.4342	0.4954	WALL BESIDE DOOR
P2	>181.8	0.3862	0.4520	WALL ADJACENT TO DOOR
P3	21.0	.8006	3.4554	WALL ADJACENT TO DOOR NEAR CEILING
P4	>126.8	0..4032	0.4474	WALL OPPOSITE TO DOOR
P5	>161.6	0.3852	0.4476	ON CEILING ABOVE CHARGE
P6	0.1276	17.3316	NO FAILURE	GROUND, LEAD BLOCK AT 10M

TABLE C2 SHOCK PRESSURE RESULTS FOR TEST THREE

PRESSURE TRANSDUCER	PEAK PRESSURE (MPa)	TIME OF ARRIVAL (ms)	TRANSDUCER FAILURE (ms)	MOUNT
P1	>37.5	0.4740	0.5918	WALL BESIDE DOOR
P2	>125.4	0.4052	0.4392	WALL ADJACENT TO DOOR
P3	>12.3	0.7676	0.7722	WALL ADJACENT TO DOOR NEAR CEILING
P4	>136.8	0.4138	0.4630	WALL OPPOSITE TO DOOR
P5	21.3	0.6122	NO FAILURE	ON FLOOR
P6	0.0692	21.2166	NO FAILURE	GROUND, LEAD BLOCK AT 10M

TABLE C3 SHOCK PRESSURE RESULTS FOR TEST FOUR

PRESSURE TRANSDUCER	PEAK PRESSURE (MPa)	TIME OF ARRIVAL (ms)	TRANSDUCER FAILURE (ms)	MOUNT
P1	12.5	0.5136	0.5.2734	WALL BESIDE DOOR
P2	>104.0	0.3602	0.3978	WALL ADJACENT TO DOOR
P3	13.7	0.8382	6.9632	WALL ADJACENT TO DOOR NEAR CEILING
P4	>34.5	0..3820	0.3900	WALL OPPOSITE TO DOOR
P5	50.7	0.4158	2.0155	CEILING DIRECTLY ABOVE CHARGE
P6	0.0797	21.3562	NO FAILURE	GROUND, LEAD BLOCK AT 10M

TABLE C4 SHOCK PRESSURE RESULTS FOR TEST FIVE

PRESSURE TRANSDUCER	PEAK PRESSURE (MPa)	TIME OF ARRIVAL (ms)	TRANSDUCER FAILURE (ms)	MOUNT
P1	6.7	1.0792	NO FAILURE	WALL BESIDE DOOR
P2	21.2	0.8298	0.8554	WALL ADJACENT TO DOOR
P3	1.4	1.5604	NO FAILURE	WALL ADJACENT TO DOOR NEAR CEILING
P4	4.5	0.7070	NO FAILURE	WALL OPPOSITE TO DOOR
P5	3.9	0.7000	1.299	CEILING DIRECTLY ABOVE CHARGE
P6	0.0483	25.7868	NO FAILURE	GROUND, LEAD BLOCK AT 10M

TABLE C5 SHOCK PRESSURE RESULTS FOR TEST SIX

PRESSURE TRANSDUCER	PEAK PRESSURE (MPa)	TIME OF ARRIVAL (ms)	TRANSDUCER FAILURE (ms)	MOUNT
P1	5.9	1.3104	NO FAILURE	WALL BESIDE DOOR
P2	19.3	1.0380	NO FAILURE	WALL ADJACENT TO DOOR
P3	1.3	1.7848	NO FAILURE	WALL ADJACENT TO DOOR NEAR CEILING
P4	4.2	0.9576	NO FAILURE	WALL OPPOSITE TO DOOR
P5	>4.8	0.9768	1.0110	CEILING DIRECTLY ABOVE CHARGE
P6	0.0357	26.0942	NO FAILURE	GROUND, LEAD BLOCK AT 10M